REMARKS

Claims 36-190 are pending. In this Response, claims 1-35 have been cancelled, and claims 36-190 have been added.

I. SECTION 112, SECOND PARAGRAPH REJECTIONS

Claims 9 and 17 are rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention.

Claims 9 and 17 have been cancelled. Therefore, Applicant respectfully requests that these rejections be withdrawn.

II. SECTION 102 REJECTIONS – LENNY ET AL.

Claims 1-2, 10-11, 22-25 and 33-34 are rejected under 35 U.S.C. § 102(e) as being anticipated by *Lenny et al.* (U.S. Patent 6,467,054).

Claims 1-2, 10-11, 22-25 and 33-34 have been cancelled. Therefore, Applicant respectfully requests that these rejections be withdrawn.

III. SECTION 103 REJECTIONS – LENNY ET AL. AND ROTHBERG

Claims 13-15, 19 and 20 are rejected under 35 U.S.C. § 103(a) as being unpatentable over *Lenny et al.* in view of *Rothberg* (U.S. Patent 6,327,106).

Claims 13-15, 19 and 20 have been cancelled. Therefore, Applicant respectfully requests that these rejections be withdrawn.

IV. SECTION 103 REJECTIONS – LENNY ET AL. AND ONO ET AL.

Claims 6 and 29 are rejected under 35 U.S.C. § 103(a) as being unpatentable over *Lenny et al.* in view of *Ono et al.* (U.S. Patent 6,636,985).

Claims 6 and 29 have been cancelled. Therefore, Applicant respectfully requests that these rejections be withdrawn.

V. SECTION 103 REJECTIONS – LENNY ET AL., ROTHBERG AND ONO ET AL.

Claim 17 is rejected under 35 U.S.C. § 103(a) as being unpatentable over *Lenny et al.* in view of *Rothberg* and *Ono et al.*

Claim 17 has been cancelled. Therefore, Applicant respectfully requests that these rejections be withdrawn.

VI. AMENDMENTS

The Title, Abstract and Specification have been amended to improve clarity. No new matter has been added.

The Substitute Specification replaces the Specification. Furthermore, the Substitute Specification amends the Specification as shown in the Substitute Specification – Changes Shown. Applicant respectfully requests that the Substitute Specification be entered.

VII. NEW CLAIMS

Claims 36-190 have been added to clarify and explicate various features of the invention. No new matter has been added.

Claim 36 recites "the manufacture test process is performed on a portion of the disk for the first time and in a particular manner depending on whether the computer system has issued the user command or the computer system is idle."

Claim 48 recites "installing the disk drive in a computer system and employing the disk drive for operations of the computer system after the disk drive leaves a factory; then . . . performing a manufacture test process on a particular area of a disk of the disk drive for the first time."

Claim 57 recites "a controller that executes the manufacture test process on a portion of the disk for the first time in response to a predetermined condition of the computer system."

Claim 71 recites "a controller that executes a manufacture test process stored in the disk drive (1) on a first portion of the disk and not a second portion of the disk while the disk drive is manufactured at a factory and before the disk drive is installed and operating in a computer system, and (2) on the second portion of the disk for the first time after the disk drive is manufactured at the factory and while the disk drive is installed and operating in the computer system."

Claim 91 recites "a controller that executes a manufacture test process stored in the disk drive (1) on a first portion of the disk and not a second portion of the disk while the disk drive is manufactured at a factory and before the disk drive is delivered from the factory and installed and operating in a computer system, and (2) on the second portion of the disk for the first time after the disk drive is manufactured at and delivered from the factory and while the disk drive is installed and operating in the computer system, thereby reducing manufacturing time for the disk drive at the factory."

Claim 111 recites "a controller that executes a manufacture test process stored in the disk drive (1) on a first portion of the disk and not a second portion of the disk using the head while the disk drive is manufactured at a factory and before the disk drive is installed and operating in a computer system, and (2) on the second portion of the disk for the first time using the head after the disk drive is manufactured at the factory and while the disk drive is installed and operating in the computer system."

Claim 131 recites "a controller that executes a manufacture test process stored in the disk drive (1) on a first portion of the disk and not a second portion of the disk while the disk drive is manufactured at a factory and before the disk drive is installed and operating in a computer system, and (2) on the second portion of the disk for the first time in response to automatic initiation by the disk drive after the disk drive is manufactured at the factory and while the disk drive is installed and operating in the computer system."

Claim 151 recites "a controller that executes a manufacture test process stored in the disk drive (1) on a first portion of the disk and not a second portion of the disk while the disk drive is manufactured at a factory and before the disk drive is delivered from the factory and installed and operating in a computer system, and (2) on the second portion of the disk for the first time in response to automatic initiation by the disk drive after the disk drive is manufactured at and delivered from the factory and while the disk drive is installed and operating in the computer system, thereby reducing manufacturing time for the disk drive at the factory."

Claim 171 recites "a controller that executes a manufacture test process stored in the disk drive (1) on a first portion of the disk and not a second portion of the disk using the head while the disk drive is manufactured at a factory and before the disk drive is installed and operating in a computer system, and (2) on the second portion of the disk for the first time using the head in response to automatic initiation by the disk drive after the disk drive is manufactured at the factory and while the disk drive is installed and operating in the computer system."

None of the art of record, alone or in combination, teaches or suggests the approach set forth above.

Lenny et al. says nothing about the disk drive performing diagnostic tests on a portion of its disk for the first time after it is installed in the host computer. Instead, as the Examiner admits, "The tests are run during manufacturing as well as after installation."

Lenny et al. also says nothing about the disk drive performing diagnostic tests on a portion of its disk in response to automatic initiation by the disk drive after it is installed in the host computer. Instead, *Lenny et al.* makes clear that "an execute drive failure prediction command must be issued to the storage device 14." (Col. 5, lines 27-28.)

Thus, claims 35-190 clearly distinguish over *Lenny et al.*, alone or in combination with the other art of record.

VIII. DRAWINGS

The Appendix with amended drawing figures attached hereto includes replacement sheets for Figures 1-3, 4A, 4B, 5, 6A and 6B. No new matter has been added.

Figures 1-2 have been amended so that the reference numbers are consistent with the Substitute Specification. Figure 2 has also been amended so that disk drive 10 is shown in broken lines and head 16, voice coil motor 18, R/W chip 30 and preamp 32 are consistent with the Substitute Specification.

Figures 3, 4A, 4B, 5, 6A and 6B have been amended to insert arrows between various blocks. Figures 3, 4A, 4B, 6A and 6B have also been amended so that "LBAs" (rather than LBA's) is consistent with the Substitute Specification. Figures 4B and 5 have also been amended to correct typographical errors in "remaining" and "ERC", respectively.

IX. FEES

The fee is calculated below:

For	Claims Remaining After Amendment	Highest Number Previously Paid For		Extra Claims	Rate		Additional Fee
Total Claims	155	– 35	=	120	x $18	=	$2160
Independent Claims	9	– 3	=	6	x $86	=	$516
Multiple Dep. Claim	0	0			$300	=	$0
Total Fee						=	$2676

Please charge the $2676 fee and charge any underpayment and credit any overpayment to Deposit Account No. 13-0016/321.

X. CONCLUSION

In view of the remarks set forth herein, the application is believed to be in condition for allowance. Should any issues remain, the Examiner is encouraged to telephone the undersigned attorney.

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class Mail in an envelope addressed to: Commssioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on November 22, 2004.

D Sigmond — 11/22/04

David M. Sigmond
Attorney for Applicant

Date of Signature

Respectfully submitted,

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SUBSTITUTE SPECIFICATION – CHANGES SHOWN

Technology Center 2100

~~Attorney Docket No. 3123-321~~

METHOD AND APPARATUS FOR MANUFACTURE TEST PROCESS ~~TEST~~ING -A DISK DRIVE INSTALLED IN A COMPUTER SYSTEM

FIELD OF THE INVENTION

The invention ~~described herein~~ relates to a method and~~n~~ apparatus ~~and method~~ for performing manufacture test processing for a disk drives~~, and more particularly to a method and apparatus for performing manufacture test processing on disk drives outside a factory setting while the disk drive is functioning in a computer system~~.

BACKGROUND OF THE INVENTION

Most computer systems include a memory storage device such as a hard disk drive for storing large amounts of data. H~~Most h~~ard disk drive ~~units~~ typically include a magnetic disk that ~~is configured to~~ stores a large amount of binary information. This magnetic disk is typically coupled to a hub that is rotated by an electric motor commonly referred to as a spin motor. In order to write information to and read information from the disk, a head is employed which magnetizes and senses the magnetic field of the disk. The head is commonly referred to as a transducer. The head is typically located at the end of a cantilevered actuator arm that ~~can~~ pivots about a bearing assembly mounted ~~on~~to a base plate ~~in the disk drive~~. The actuator arm has a coil which cooperates with a~~the~~ magnet mounted ~~on~~to the base plate. Providing ~~a~~ current to the~~tube~~ coil creates ~~a~~ torque on the actuator arm and moves the head relative to the disk. The coil and magnet are commonly referred to as a voice coil motor ~~or VCM~~.

The d~~Hard d~~isk drive ~~units~~ contains ~~a number of~~ integrated circuits that control the operation of the drive. The circuits typically include a read/write channel that is coupled to the head~~transducers~~ and ~~of the actuator arm assembly. The read/write channel connected to~~ an

interface controller ~~which is coupled to the host computer~~. The interface controller is coupled to the host computer and ~~coupled to~~ a random access memory (RAM) ~~device that is used as a~~ buffer to store data transferred between the disk and the host computer.

D~~An essential component to operating of the memory storage system is the magnetic disk. Typically d~~ata is recorded on the disk in the form of magnetic transitions spaced closely together. In modern disk drives ~~in particular~~, recording densities both in terms of ~~ratio~~ tracks per inch and linear density along a track have reached a level which creates extreme sensitivity to imperfections in the disk. T~~t~~hese imperfections are known as media defects~~,~~ and occur in the magnetic recording layer of the disk. Media~~These~~ defects cause~~which results in~~ portions of the magnetic recording layer to be~~coming~~ unacceptable for ~~use in~~ recording the magnetic transitions. Media defects can~~may~~ be small, affecting only a small number of transitions on a small number of tracks, or large, affecting many transitions across multiple tracks.

Manufacturing tests processes are performed on the disk drive at the factory prior to its installation in a computer system. These tests include flaw mapping, embedded runout compensation (ERC) and final drive verification.

Flaw mapping performs a write/verify process over the tracks to identify logical block addresses (LBAs) which possess defects and may not be able to receive and store information. The locations of LBAs with defects are stored in a flaw map. ERC corrects irregularities in the shape of the tracks (cylinders). An error value is generated which indicates the distance between the head and the center of the track at a particular location on the track. The error value provides alignment correction for the head during the read/write process for a particular track on the disk. Final drive verification is a follow-up to flaw mapping that confirms that the LBAs do not contain flaws.

Unfortunately, these manufacture test processes are very time consuming. As the number of tracks in the disk drive has increased, the total number of passes made at each location in performance of these tests has increased which in turn increases the manufacture time for the disk drive.

SUMMARY OF THE INVENTION

~~In order to detect media defects, a number of manufacturing tests processes may be performed on a disk drive at the factory prior to its installation in a computer system. These tests may include flaw mapping, wherein a write/verify process is performed over each of the radial tracks to identify logical block addresses (LBAs) which possess defects and may not able to receive and store information. The locations of LBAs with defects which are discovered during flaw mapping may be then stored in a flaw map for the disk. Other tests which may be performed include runout compensation which checks and then provides corrections for irregularities in the shape of the tracks (cylinders), as well as final drive verification.~~

~~The performance of these manufacture test processes may a be very time consuming process.~~ ~~T~~As ~~such,~~ the present invention~~inventor has~~ teaches~~recognized~~ that ~~disk drives may be designed such that instead of having the manufacturing test processes performed in the factory prior to installation, a number of~~ manufacturing tests processes can~~may~~ be automatically performed by the disk drive once it is activated and operational in a computer system rather than in the factory prior to installation of the disk drive.

The present invention ~~Described herein is a method and apparatus for~~ perform~~s~~ing automated manufacture test processes on a disk drives once the disk drive is installed and operating within a computer system. The invention includes~~system described herein may be~~

~~configured as~~ a processing module ~~which is~~ locate~~dable~~ in a memory of~~for~~ the disk drive, and~~where~~ the memory can be ~~for the purposes of the system described herein may include any sort of information storing device, such as~~ a processed portion of the disk ~~drive~~, a random access memory (RAM), ~~and~~ a read only memory (ROM), as well as any combination of these devices. The ~~Included in the~~ processing module includes ~~may be~~ sequences ~~which are employable~~ to perform ~~a number of~~ automated tests. The test procedures and other saved information are~~is~~ retrievable by a~~the~~ processor of the~~a~~ disk drive such that the testing is~~may be~~ performed at predetermined times.

In an~~one~~ aspect of the invention, the test ~~to be performed may~~ includes at least one of~~:~~ flaw mapping, embedded runout compensation~~,~~ (ERC) and~~as well as~~ final drive verification ~~pass~~. F~~The performance of the~~ flaw mapping ~~may~~ includes initiating write/verify tests of LBAs on the disk~~recording media during~~ either during normal write commands for the disk drive~~,~~ or ~~during periods of time~~ when the computer system is ~~in an~~ idle ~~mode~~. F~~More particularly, the~~ flaw mapping makes~~module may be configured such that~~ an initial query ~~may be made~~ as to whether any user commands are pending. If a write command is pending, an analysis determines~~may be made as to~~ whether the addresses to which the information is~~are~~ to be written are LBAs which have been previously processed. If not, during the write function to these LBAs a verify ~~may be performed to~~ determines whether the information was stored correctly. If ~~it is determined that~~ the information was not stored correctly, the LBA is~~may be~~ reassigned to a processed area of the disk and a pointer provided at the original location to direct all future read and write functions to the new location. As LBAs are processed, ~~various~~ counters are~~may be are employed and~~ continually updated and saved to track which ~~of the~~ LBAs have been processed. The processing module also performs~~is further configured to determine when~~ a write function ~~is to perform~~ in an

area which includes both processed and unprocessed LBAs. The processing module ~~will~~ performs write functions to processed areas and then perform write/verifies on the unprocessed area before the information is permanently written to a particular LBA.

When~~In the situation where~~ there are no user commands pending and the computer system is ~~an~~ idle ~~mode~~, the processor ~~may be configured to~~ performs the write/verify tests on LBAs using test information. As an initial step, information is ~~may be~~ retrieved from memory which indicates which of the LBAs have been tested and which have not. Once the next unprocessed LBAs are identified, the write/verify functions are performed and all ~~the~~ LBAs which have flaws are reassigned to a processed area of the disk and pointers are provided at the previous location. Once a particular increment of the LBAs is processed, a pointer is ~~may be~~ updated and a check made as to whether any user commands are pending.

A further test is~~performed by the automated system may include~~ embedded runout compensation (ERC). Unlike the flaw mapping, the ERC~~runout compensation~~ typically is not performed when a user command is being performed or pending. Instead, the ERC ~~This test~~ is performed during idle times and an error signal is generated which is ~~may be~~ stored in memory and ~~which~~ provides a correction for the ~~read/write~~ heads ~~of the disk drive~~. An initial query also asks~~which may be made as to~~ whether a user command is currently pending. If ~~there is~~ a user command is pending, it is performed and the ERC~~runout compensation~~ test is ~~will~~ not ~~be~~ performed until ~~there is a detected~~ idle time. If ~~an~~ idle time is detected, a~~t least one~~ counter is accessed from memory to identify which of the cylinders is ~~next to be~~ processed next. ~~To~~ track the completion of the ERC~~the runout compensation~~, ~~various~~ counters ~~are maintained which~~ indicate which cylinders have been tested and which have not. Further, ~~various schemes may be established such that~~ various cylinders are ~~may~~ not ~~be~~ employed during normal operations of the

disk drive until an ~~t least one~~ adjacent cylinder has also been tested. Separate pointers ~~may be employed to~~ track both of these items.

Once the next cylinder to be processed is identified, the ERC~~runout compensation~~ for that cylinder is performed and an error signal is generated and stored in memory. Further, ~~all~~ the counters that ~~employed to~~ track which cylinders have been processed are updated and stored in memory. ~~-~~Another query ~~may~~ then asks~~be made as to~~ whether there are any user commands pending. If there are, those commands are performed, if not, another cylinder is tested until all unprocessed cylinders are processed.

Final drive verification ensures that ~~In order to ensure that all~~ the LBAs which were tested are not flawed~~, a final verification pass may be made~~. As with the flaw mapping test described above, this test is ~~may be~~ automatically initiated either during idle times or performed ~~in conjunction~~ with write functions ~~performed~~ as part of user commands. If the final drive verification is performed as part of a user command, previously saved counter information is accessed ~~and employed~~ to determine~~d~~ whether the final drive verification has been performed previously on any of the LBAs to which a write is to occur. If not, the write function is performed on the LBAs and the information is verified. If any errors are detected, the LBAs are reassigned and a pointer is generated to direct all future write functions to the reassigned LBAs. Once the write function is complete, the necessary pointers are updated and a further query asks~~is made as to~~ whether any user commands are pending.

If the computer system is ~~in~~ idle, ~~the~~ counter information is retrieved from memory and an increment of LBAs are identified for which the final verification test is to be performed. ~~-~~At this point, the information stored on these LBAs is read and verified. If any errors are detected,

the effected LBAs are reassigned and a pointer is included in the diskmedia. At this point, the counters are updated and the system returns to its initial query.

In anotherone aspect of the invention, portions of the test described above aremay be performed at the factory prior to the disk drive being installed in the computer system in order to detect any major flaws which may exist in the disk. For example, a certain percentage of the LBAs and cylinders at designated locations on the diskmedia aremay be tested so as to identify any major flaws which may extend across multiple LBAs or cylinders.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 idiscloses a top view of a magnetic disk in a disk drive along with and an actuator arm in a disk drive.

Figure 2 idiscloses an electronic system diagram offor the disk drive.

Figure 3 idiscloses a flow chart of which describes the steps performed for a write/verify function during flaw mapping of a disk drive.

Figures 4A and 4B arediscloses a flow chart of which describes the steps performed by the disk drive during automated flaw mapping operations.

Figure 5 idiscloses a flow chart ofwhich describes the steps performed by the disk drive during automated ERCrunout compensation testing.

Figure 6 idiscloses a flow chart ofwhich describes the steps performed by the disk drive during automated final drive verification.

DETAILED DESCRIPTION

~~Disclosed in~~ Figure 1 shows ~~is a~~ hard disk drive 10 ~~configured~~ in accordance with the present invention. D~~The~~ disk drive 10 includes ~~a~~ magnetic disk 12, actuator arm 14, read/write head 16, voice coil motor 18 and spin motor 20. D~~that is rotated by a spin motor 18. The~~ disk 12 is ~~may be~~ constructed from ~~a~~ metal, glass, ceramic or a composite substrate that is covered with a magnetic coating as is known in the art. Disk 12 is rotated by spin motor 20. D~~The~~ disk 12 rotates relative to ~~an~~ actuator arm ~~assembly~~ 14~~3~~ which supporthas ~~a pair of~~ head (or heads)~~transducers~~ 16~~5, commonly referred to as heads~~. H~~The~~ eadtransducers 16~~5~~ contains a coil (not shown) which can magnetize and sense the magnetic field of the ~~each~~ corresponding adjacent surface of ~~the~~ disk 12. ~~Each head is supported by actuator arm 13.~~ At the opposite end of ~~the~~ actuator arm 14~~3~~ from ~~the transducer~~ heads 16~~5~~ is ~~the~~ voice coil motor 18~~6~~. ~~Connections run from the voice coil motor to the various electronics of the system.~~ V~~The~~ voice ~~motor~~ coil motor 18~~6~~ ~~is employed to~~ rotates ~~the~~ actuator arm 14 and head~~transducers~~ 16 such that ~~the transducer~~ heads 16 is~~may be~~ positioned ~~in the appropriate positions in order~~ to read or write information on ~~the~~ disk 12.

Data is ~~typically~~ stored on ~~a magnetic~~ disk 12 along annular tracks concentric within the diameter of ~~the~~ disk 12. D~~The~~ disk 12 can~~may~~ have various diameters such as~~be any number of sizes which includes an~~ 1.8 inch", 2.5 inch", 3.5 inch", etc.~~, diameter disk.~~ For example, with a 1.8 inch disk, the system will typically store data on a 130 tracks per disk surface. In one configuration, e~~E~~ach track contains ~~a plurality of~~ servo sectors and e~~in one configuration of the invention. E~~ach sector is capable of storing up to 768 bytes of data. The total assembly is capable of storing up to 130M of data.

Figure 2 ishowss a schematic of the electronic system architecture of ~~the hard~~ disk drive ~~assembly~~ 10. The system includes data manager 22, controller 24, servo 26, read only memory (ROM) 28, read/write (R/W) chip 30 and preamp 32. ~~a~~ Ddata manager 228 ~~which~~ provides ~~for~~ ~~the~~ data exchange between ~~the~~ disk drive 10 and ~~the~~ host computer 34~~system~~. C~~In connection with the data manager is the~~ controller 2430 ~~which~~ provides control signals for ~~the~~ various electrical components of ~~the~~ diskhard drive 10. For instance, ~~Connections are established from the~~ controller 2430 is connected to servo 26 ~~to a number of components such as servo 20~~ which controls the operation of ~~the~~ voice coil motor 1822 and ~~the~~ spin motor 2024. Controller 24 is also connected to ROM ~~Further connections are established from the controller to read only memory (ROM)~~ 2834 whichupon stores ~~which~~ software that runswhich ~~the~~ disk drive 10~~employs to run may be stored~~. R~~The read~~/W~~write~~ ~~(R/W)~~ chip 302 controls the read/write functions for data stored on and received from the disk 12 through head 16 and pre-amp 326 ~~and pads 38~~.

In operation, ~~the~~ disk drive 10 is installed in ~~a~~ host computer 34~~system~~. D~~The~~ disk drive 10~~electronics may~~ receives a request from ~~a~~ host computer 3426 for reading or writing data on ~~the~~ disk 12. D~~The~~ data manager 228 ~~will~~ receives the requests from ~~the~~ host computer 34 in the form of ~~a~~ logical block addresses (LBAs). This information is provided to ~~the~~ controller 2430 which in turn converts the logical block addresses to physical disk addresses. C~~The~~ controller 24~~chip 30 may~~ then initiates a seek routine through ~~the~~ servo 260, which in turn moves ~~the~~ heads 16 to the proper location on ~~the~~ disk 12. When ~~the~~ voice coil motor 18 has moved ~~the~~ head 16~~transducer~~ to the desired disk sector, ~~the~~ controller 24~~chip~~ provides a z-sector signal to ~~the~~ data manager 22. Upon receiving the z-sector signal, the read or write function is~~may be~~ initiated and the necessary functions performed using head 16, ~~the~~ R/W chip 302 and pre-amp

326 and the heads 38. The data extracted by the R/W chip 300 is max then be provided through the data manager 22 to the host computer 3426.

To ensure that the disk drive 10 is able to operates in a host computer 34 substantially as described above, a number of manufacturing tests processes aremay be performed on the disk drive 10. -Typically, the manufacturing test processes are performed at the factory prior to installation of the hard disk drive 10 in a host computer 34. According to the present invention described herein, while some a number of manufacturing tests can may be performed prior to installingation of a disk drive 10 in host a computer 34system, othera number of these manufacturing test processes canmay be be performed while the disk drive 10 is installed and operating within a host computer 34 system.

As is known, flaws on a disk in a disk drive will affect its performances. Defects to areas of the disk will make it so that reading and/or writing of information to these areas of the disk is not possible. In order for a disk to operate properly, these defects are identified and appropriate pointers placed on the disk such that the information may be read or written to another area on the disk which is without defects this is know as flaw mapping.

Another issue which may affect the ability to read and write information on a disk relates to maintaining the read/write heads in alignment relative to the center of the continuous track on which information is stored or to be stored. Problems may arise in that the axis of rotation of the disk is not precisely the same as the center of the concentric tracks located on the disk or, a slight deviation was created with regards to one of the concentric tracks during the manufacture of the disk such that it temporarily moves out of its circular shape with regards to the axis of the disk. In operation, these areas should be compensated for such that the tracking of the read/write heads

~~may be varied when information is to be written or read on this particular area of the disk. Compensation for these rotation problems is known as runout compensation.~~

~~Other tests which may be performed include drive verification which checks the mechanical aspects of the drive, servo optimization through which calibrations of the mechanical aspects and the head locations may be performed, data optimization wherein certain calibrations are performed and tolerances determined with regards to the different components of the disk drive.~~

~~As described above, the test for embedded run-out compensation, flaw mapping, and drive verification may be performed prior to the installation of the disk drive in a computer system at the factory. However, as the number of tracks in a disk drive has increased, the total number of passes made at each location in performance of the above described tests has increased which in turn increases the production time required for the manufacture of the disk drives. According to the invention described herein the disk drives may be configured such that a number of manufacture process testing may be performed once the disk is installed in the host computer.~~

D~~The~~ disk drive 10~~described herein,~~ is equipped with the functionality to perform a number of automated self test procedures. In the embodiment described herein, the self test procedures include flaw mapping, ~~encompass~~ embedded run-out compensation (ERC)~~, flaw mapping,~~ and final drive verification. In view of the teachings of the present invention, o~~O~~ne skilled in the art would realize that any number of tests can ~~may~~ be performed in an automated fashion while ~~the~~ disk drive 10 is installed and operating in ~~a~~ host computer 34 ~~system~~. These ~~steps performed in those~~ tests ~~also~~ fall within the scope of the present invention.

During the manufacture~~ing~~ of ~~the~~ disk drive 10, manufacturing ~~a number of~~ tests such as drive functionality and data optimization are~~may be~~ performed at the factory. Additionally, flaw mapping, ERC~~,~~ and final drive verification are ~~may be~~ performed over a limited area of~~ver the~~ disk 12 to assure ~~that~~ there are no major flaws in ~~the~~ disk 12. T~~, and~~herefore, ~~a at least~~ a portion of ~~the~~ disk 12 is processed and ready to store data once ~~the~~ host computer 34 ~~system~~ is operational. For ~~As an~~ example, at the factory, flaw mapping and ERC are~~may be~~ performed for the first 10 percent of the LBAs. D~~The~~isk drive 10~~drive~~ is~~would~~ then ~~be~~ flaw mapped and ERC is performed for every N tracks of the remaining disk surface to assure ~~that~~ there are no very large defects and ~~to be able to~~ predict the total number of defects. A processed pointer is~~may~~ then ~~be~~ initialized and stored on ~~the~~ disk 12~~media~~ indicating the portions of ~~the~~ disk ~~drive~~ 12 that have been already processed. Also during the factory manufacturing ~~process~~, an automated test program described ~~in detail~~ below is~~may be~~ written into the memory of disk drive 10. The memory can be ~~, where memory for the purposes of the system described herein may include any sort of information storing device, such as~~ a processed portion of ~~the~~ disk drive 10, a random access memory (RAM), ~~and~~ a read only memory (ROM), and ~~as well as any~~ any combination of these devices.

Once the manufacturing testing processes ~~performed~~ at the factory are complete, ~~the~~ disk drive 10 is~~may be~~ installed in ~~a~~ host computer 34 ~~system~~. T~~According to the invention described herein, t~~he unprocessed portions of ~~the~~ disk 12 are then ~~may be~~ automatically processed during normal operations of ~~the~~ host computer 34 ~~system~~. For example, ~~In particular,~~ this automated processing ~~may~~ occurs during write functions to unprocessed areas of ~~the~~ disk 12 and ~~during~~ disk drive idle time (no user commands pending). This testing is substantially interruptible and

does ~~so as to~~ not significantly reduce the performance of the disk drive 10 during user commands for read and write functions during normal operations.

As ~~was~~ described above, ~~some~~ tests ~~which maybe~~ performed during normal operations of ~~the~~ host computer 34 ~~system~~ include flaw mapping, ERC~~embedded runout compensation,~~ and final drive verification. ~~-~~As part of the flaw mapping and final drive verification, write or read/verify tests are performed which determine ~~basically conclude~~ whether a particular LBA is able receive ~~and~~ data when written to.

~~Disclosed in~~ Figure 3 is a flow chart of ~~which describes in the~~ steps performed during a write/verify test which is employed by the automated test procedures described below. ~~-~~As an initial step a list of LBAs to be analyzed is identified. The first LBA in the list is identified and the test procedure begins with test information being written to the LBA. ~~–~~The LBA is then read and the information read from the LBA is compared against the test information. ~~-~~A determination is then made as to whether the~~-~~ read information is identical to the test information. If any differences in the information read from the LBA are detected, a determination is ~~may be~~ made that the particular LBA is flawed. If so, the LBA is re-assigned to another area on ~~the~~ disk 12 and a pointer is placed on ~~the~~ disk 12 indicating the new location for the LBA~~-~~.

If the information read from the LBA matches the test information, the LBA is determined to be functional and ~~this may be updated in~~ the flaw map is updated for ~~the~~ disk 12. At this point the next LBA in the particular increment is~~may be~~ tested, and the flaw mapping continues until all LBAs in the particular increment are tested.

The flaw mapping process described above is employed as part of the automated flaw mapping procedures for disk drive 10~~s which described herein~~.

~~Disclosed in~~ Figures~~.~~ 4A~~a~~ and 4B~~b~~ are~~is~~ a flow chart of ~~which describes in detail~~ the steps performed by the automated flaw mapping process once ~~a~~ disk drive 10 is installed in ~~a~~ host computer 34~~system~~ and ~~the~~ host computer 34~~system~~ is operational. As an initial step not shown in the flow chart, at start-up of ~~the~~ host computer 34, the processor of~~for~~ ~~the~~ disk~~hard~~ drive 10 ~~may~~ issues an instruction to execute a software program, which is either stored on ~~the~~ disk 12 or in ROM, to perform the automated tests. Once this software program is loaded and running, the system is ready to initiate the automated self test. As a first step, a query asks~~is made as to~~ whether a user command is currently pending. User commands are instructions which direct ~~the~~ disk drive 10 to read or write information on ~~the magnetic media of the~~ disk ~~drive~~12. If ~~there is~~ a user command is pending, a determination is made as to ~~as to~~ whether it is a read or write command. If ~~it is~~ a read command is detected, disk drive 10 operations ~~will~~ proceed normally. If a write command is detected, the process~~a~~ determines ~~ation is then made as to~~ whether the LBA's to which the information is to be written are in a processed or unprocessed area of disk 12~~the magnetic media~~. When ~~the~~ disk 12 is delivered from the factory, certain areas of ~~the~~ disk 12 are~~may~~ already ~~be~~ flaw mapped and this is ~~may be~~ recorded on a flaw map for ~~the~~ disk drive 10 which is accessible in memory. Further, as different areas of ~~the~~ disk 12 are processed through the flaw mapping process, this is indicated in the flaw map.

Returning ~~again~~ to Figure~~.~~ 4A~~a~~, if the entire area which information is to be written is unprocessed, then ~~the~~ disk drive 10 ~~will~~ performs a write of the information and then a verify of what ha's been written. If the write/verify step fails, a reassignment of the LBAs which failed is performed, the information is written to a processed area of ~~the~~ disk 12, and a pointer is placed on ~~the~~ disk 12 which identifies the location of the reassigned LBAs. The pointer also indicates that the flawed area of ~~the~~ disk 12 should not be used.

If it is determined during the write function that a first portion of the data is to be written to an unprocessed area and a second portion is to be written to a processed area, a write is initially performed to the processed area. With regards to the unprocessed area, the write/verify test is performed for the LBAs included therein. If the verify fails, there is a reassignment of the LBAs to new locations on ~~the~~ disk 12 and a pointer is provided which redirects all future reads and writes to the new LBAs. In the last scenario, a determination is ~~may be~~ made that the write is being performed to an area which has been ~~all~~ processed. In this case, there is no need to perform an automated test and the write function is performed normally.

In order to track the progress of the testing, ~~a number of~~ counters are incorporated in the automated test program. One counter is the process LBA counter which ~~provides an~~ indicates~~ion of~~ the last LBA which was processed. During various program cycles ~~of the program described herein~~the, counters are continually updated in ~~the~~ case of interruptions due to user commands or power losses.

The system ~~described herein is designed to~~ performs the automated tests until the entire disk 12 is~~has been~~ analyzed. As such, the automated program ~~is further configured to~~ tests areas of ~~the~~ disk drive 12 during detected idle times. Returning to the initial steps ~~of the flow chart~~ in Figure~~.~~ 4A~~a~~, if ~~it is detected that there is~~ no user commands are pending, the automated self test disclosed in Figure~~.~~ 4B~~b~~ is~~may~~ then ~~be~~ initiated. ~~-~~Initially, a counter saved in memory is~~may be~~ accessed to ~~make a~~ determine~~ation as to~~ the last increment of LBAs to be processed and ~~to~~ identify the next increment of LBAs to ~~which may~~ be processed.~~:~~ ~~-~~The number of LBAs included in an increment is~~may be~~ limited so as not to take enough time to unduly interfere with normal operations of host~~the~~ computer 34~~system~~. ~~-~~During the time ~~that~~ the~~is~~ automated process is ~~being~~ performed, ~~the~~ disk drive 10 is~~may be~~ inaccessible.

Returning to Figure 4B~~again to the flow chart of Fig. 4b~~, an additional query asks~~may be made as to~~ whether there are enough LBAs left to be processed for a normal processing increment. If there enough LBAs for an increment, ~~a~~ the test information is retrieved and employed in a write/verify step for each LBA. ~~–~~Any LBAs which fail the write/verify test are reassigned and a pointer is provided on ~~the~~ disk 12. Once all the LBAs in an increment are tested, the defect map stored in memory is updated, and likewise, ~~as well as~~ the counter which indicates which LBAs have been processed is updated. ~~-~~Another increment of LBAs will be identified and tested unless a new user command is detected or there are no more unprocessed LBAs left ~~unprocessed~~.

~~In the situation where~~ there is not a normal increment of LBAs for performing the automated processing, the remaining unprocessed LBAs are automatically tested and the defect map is updated and the number of good LBAs are identified. The LBAs tested are moved from unprocessed space to processed space. The testing program is then updated to indicate that the flaw mapping test is complete.

~~Another automated test which may be performed while the disk drive is operating within the computer system is embedded runout compensation (ERC). Runout compensation relates to the ability to properly align the head of the read/write mechanism when reading or writing information from the spinning hard disk. This alignment is important so that information can be read accurately and/or stored properly. A problem commonly arises however in that the access and rotation of the disk in the disk drive is not precisely the same as the center of the concentric tracks located on the disk. This lack of correspondence between the axis of rotation of the disk and the center of the concentric disk tracks result in a displacement of the head relative to the track center during the spinning or rotation of the disk.~~

~~In order to correct for any displacements, the misalignment may be measured and an error value generated which relates to the distance the head is away from the center of the track at a particular location on the track. These error values may be stored employed by the disk drive to provide alignment corrections for the head during the read/write process for a particular track on the disk. The processes employed during runout compensation to generate these error values are well known in the art and will not be described herein.~~

~~———~~Figure 5~~Disclosed in Fig. 5~~ is a flow chart of ~~which describes in detail~~ the steps performed by the automated system when performing ERC. As ~~was~~ noted above~~before~~, a first step (not shown) is the downloading and execution of a program which is either stored in ROM or on a processed area of ~~the~~ disk 12. A first query made in the automated test procedure ask~~is~~ ~~to~~ whether a user command is pending for reading or writing information on ~~the~~ disk 12. If a user command is pending, the system will discontinue performing the automated test functions and perform the requested user commands. After the command is complete, and the system returns to ~~is back in~~ idle mode the query is ~~will be~~ made again.

If there are not user commands pending, a first query asks ~~will be made as to~~ whether there are any unprocessed tracks (cylinders) left to be tested. As in flaw mapping, the disk space ~~may~~ is~~be~~ broken ~~up~~ into three areas. The first (lower) is the process area which includes user LBAs. The second (middle) in the unprocessed area which does not contain user LBAs. The third (top) is the unprocessed area which also contains user LBAs. The ~~processing for~~ ERC is executed from the lower to higher areas until all processing is complete. Since the ~~the~~ ERC ~~processor~~ modifies (straightens) the path ~~(straightens)~~ of the heads, user data will not be moved to the process cylinder until the cylinder being tested (target) and target +1 cylinders have been processed. In order to perform the testing, ~~a number of~~ counters are employed. These include

the last process user's cylinder as well as the last process cylinder. The last processed user cylinder indicates the last cylinder which has been processed which is available for storing data. The disk drive is ~~may be~~ configured at the factory such that the last processed user cylinder equals -1 and the last process cylinder also equals -1.

Returning ~~again~~ to Figure~~.~~ 5, if ~~it is determined that there are~~ unprocessed cylinders are left, the last processed cylinder pointer is accessed to determine which cylinder is next to be processed. Once the next cylinder to be processed is identified, the ERC is performed and the error information for that particular cylinder is stored in memory. After this information is generated the various pointers employed are ~~will~~ also ~~be~~ updated. For example, the last processed cylinder is incremented up one as is the last processed user cylinder. This information is then saved in memory. —The process then returns to start and if no user commands are pending the next unprocessed cylinder is processed.

Figures 6A and 6B are a ~~Yet another automated process which may be performed once a hard drive is installed on a computer system is a final verification pass. The final verification pass is employed as a follow-up to the flaw mapping to confirm that the all the LBAs which were processed and shown to be without flaws, are able to be written to. The~~ flowchart of the ~~which describes~~ steps performed in ~~this~~ final drive verification ~~pass is disclosed in Fig. 6a-b~~. As an initial step, a query asks~~is made as to~~ whether a user command is pending. If there is a user command pending, the process determines ~~a further determination is made as to~~ whether it is a read or write command. If it is a read command, the read function is performed without interruption and the automated program returns to its initial query. If it is a write command, yet another query asks~~is made as to~~ whether the write is to a processed or unprocessed area (with regards to the final drive verification test). If the write command is to an area which has been

processed, the write function is performed without interruption and the program returns to its initial query.

A query then asksis then made as to whether the area to which the write command is to be carried out includes -any unprocessed LBAs. In particular, a query asks will be made as to whether all the writes are to an unprocessed area. If this is the case, each LBA to which a write is to occur has a write/verify test performed as such as that described in Figure. 3. All LBAs which fail the write/verify will be re-assigned and a pointer provided on disk 12the media. Further, the flaw map will be updated to indicate the flawed LBAs. When the processing for particular increments of the disk drive 12 is performed, the counter which tracks the -LBAs which have been processed is updated by adding the processing increments. At this point, the automated program will returns to the initial query.

If the area to which information is to be written contains both processed and unprocessed LBAs, all the writes are initially performed to the processed area. Once the unprocessed area is reached, the write/verify test is performed on all of the unprocessed LBAs. At this point, the LBAs which fail are reassigned and pointers are provided at the location. Further, the flaw map is updated, as arewell as the counters which will provide indicateion of where the future cycles of the test are to begin.

Turning again to the first query of Figure. 6Aa, if there are no user commands pending, the final drive verification test program will then retrieves the stored information and counters which indicate where the write/verify test is to continue from. Typically, a predetermined processing increment is employed to identify the number of LBAs which will be tested during a particular cycle of the test. A first query asksmade is to whether there are any LBAs left to process. If there are not, the process ends. If there are LBAs to be processed, a further query

asks ~~is made as to~~ whether there are enough LBAs in a normal processing increment. If there are not, this indicates that the end of the test is about to be reached, and ~~as such~~ the remaining LBAs are tested. In this situation, because information had been previously written to these LBAs either through the write/verification test and/or during normal operations this information is read from the particular LBA and is checked for accuracy. If an error is detected, the LBA is reassigned and a pointer is provided. The flaw map is then updated and then the LBA pointer is also updated to indicate that all of the LBAs have been read during the final drive verification pass.

If ~~it is determined that~~ there are enough LBAs to fill a processing increment, the final drive verification test program ~~will then~~ performs ~~the test such that~~ the read verify function ~~is performed~~ on the LBAs in the increment as ~~was~~ described above. If any of the LBAs are ~~shown to be~~ flawed, the LBA is reassigned and the flaw map is updated. Once the test for an increment is complete, the LBA counter which indicates which LBAs have been processed is incremented upwards. This information is then saved in memory and the test program returns to the initial query.

Disk drive 10 installed in host computer 34 can implement other automated manufacturing test processes, such as servo optimization, data optimization, mechanical check and determination of tolerances of different components in disk drive 10.

The foregoing description of the present invention has been presented for purposes of illustration and description. Furthermore, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, and the skill or knowledge of the relevant art, are within the scope of the present invention. The embodiments described ~~herein~~above are further intended to explain best

modes known for practicing the invention and to enable others skilled in the art to utilize the invention in such, or other, embodiments and with various modifications required by the particular applications or uses of the present invention. It is intended that the appended claims be construed to include alternative embodiments to the extent permitted by the prior art.